World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:3, No:5, 2009

The project of three photovoltaic systems in an Italian Natural Park

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***Abstract*—**The development of renewable energies - particularly energy from wind, water, solar power and biomass - is a central aim of the European Commission's energy policy. There are several reasons for this choice: renewable energies are sustainable, non-polluting, widely available and clean. Increasing the share of renewable energy in the energy balance enhances sustainability. It also helps to improve the security of energy supply by reducing the Community's growing dependence on imported energy sources.In this paper it was studied the possibility to realize three photovoltaic systems in the Italian Natural Park "Gola della Rossa e di Frasassi". The first photovoltaic system is a grid-connected system for Services and Documentation Center of Castelletta with a nominal power of about 6 kWp. The second photovoltaic system is a grid-connected integrated system on the ticket office's roof with a nominal power of about 4 kWp. The third project is set up by five grid-connected systems integrated on the roofs of the bungalows in Natural Park's tourist camping with a nominal power of about 10 kWp. The electricity which is generated by all these plants is purchased according to the Italian program called "Conto Energia". Economical analysis and the amount of the avoided CO_2 emissions are elaborated for these photovoltaic systems.

***Keywords*—**CO_2 emissions, Conto Energia, Photovoltaic Systems.

I. Introduction

THE human population of the earth has now passed 6 billion and all of this inhabitants want the energy necessary to sustain their lives.

Exactly how much energy is required to meet these needs and exactly what sources of energy will meet these needs will be questions to be addressed by the present and by future generations [1].

The sun is one of the most important source of energy. Thanks to our technology it can be used in a very efficient way.

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The use of integrated photovoltaic building systems is one of the most important elements in modern architecture.

Through photovoltaic cells (PV) it is possible to generate electricity directly from the sun without any harmful emissions like CO_2, NO_x and SO_x.

In recent years the climatic changes and the sustainable development have become more and more important and the market's attention is actually focused on these topics .

Different projects were born like the local Agenda 21, the European White Paper on Energy and the Kyoto Protocol.

In 2007 the countries of the EU installed photovoltaic systems for a total capacity of 1 541.2 MWp so total European installed capacity was about 4 689.5 MWp . Even if a large part of this capacity is due to the German market's dynamism, an even larger portion comes from the long awaited rise in importance of new markets.

The ratio of photovoltaic capacity per EU inhabitant is actually at 8.5 Wp per inhabitant. More than ever, the European market remains focused on grid-connected power plants, representing 99.5% of the new installed supplementary capacity. Direct consumption of electricity for off-grid connections (electrification of isolated sites, public lighting, etc.) only represented 8.4 MWp in 2007.

The Italian market's increasing importance was confirmed in 2007: an additional capacity of 50.2 MWp (49.8 MWp grid-connected and 0.4 MWp off-grid)was installed. This is four times more than in 2006 when 12.5 MWp were installed. In this way, Italy becomes the third EU country to pass the mark of 100 MWp of installed capacity [2].

National, regional and local authorities are creating different incentives and financial support. In this way it is possible to give new opportunities to the spread of PV plants to produce clean energy.

The municipalities and their partners can obtain very good results using photovoltaic systems both under an economic point of view and under their public image.

In this paper three photovoltaic plans in the Italian Natural Park "Gola della Rossa e di Frasassi" were studied.

II. The Italian Support Program

The Ministerial Decree dated February 19th 2007 defined

criteria that provide incentives for electricity generation by photovoltaic solar plants.

This tariff varies as a function of plant capacity (from 1 to 3 kWp, from 3 to 20 kWp and more than 20 kWp) according to the typology of photovoltaic installation (power plants that are integrated or not in the buildings and ground based PV systems).

The incentive is valid for a period of 20 years and varies from 0.49 €/kWh, for power plants integrated in buildings with capacities lower than 3 kWp, to 0.36 €/kWh, for non-integrated and ground based PV systems, more than 20 kWp installed in 2007 and in 2008 (Table I):

TABLE I
INCENTIVES

Power Class	Not integrated (€ / kWh)	Partially Integrated (€ / kWh)	Integrated (€ / kWh)
1kW ≤ P ≤ 3kW	0.40	0.44	0.49
3kW < P ≤20kW	0.38	0.42	0.46
P > 20kW	0.36	0.40	0.44

An annual price decrease of 2% will be applied from 2009.

The incentive is applied to the electricity generated: it is measured at the output terminals of the direct current-alternating current converter. For systems not exceeding 20 kW with the option "Scambio sul Posto" (net metering), the incentive is only applied to the electricity generated and consumed on site.

The incentives will be reduced of 5% in some particular cases [3].

The "Gestore dei Servizi Elettrici" (GSE - Electric Services Administrator) is the authority that will assess the incentive applications in accordance with the provisions of the Ministerial Decree.

III. THE CASES STUDY

The installation of a PV systems on surfaces of a building makes possible to combine electrical energy production with other functions of the building structures**.** Grid-connected PV systems represent a reliable solution for electricity supply in buildings; in fact the investment's costs are reduced because no land is required, the support structure is less expensive, non storage batteries are needed. Moreover electricity is generated at the point of use avoiding the transmission and distribution losses. The characteristics of flexibility and modularity of the PV technology allow the installation in urban areas on existing structures; this solution can contribute to the local power requirements without interfering with the environment and reducing greenhouse emissions. The Natural Park "Gola della Rossa e di Frasassi" was born in September 1997 and is a protected area. The great variety of the ecosystem and of the environmental conditions allows the development of different kinds of flora and fauna species of considerable naturalistic interest.

A. The operative seat of the Park

The system planned for the operative seat of the Park is a partially integrated system and was planned on the annual electric energy consumptions.

It is a 5.94 kWp grid-connected PV array located on the roof of the building and it occupies a shadows-free area of about 46 m^2.

The grid-connected plant is realized with 36 polycrystalline PV modules of 165 Wp in standard conditions.

The modules are south-east facing on a roof that has 17° of inclination. The modules are connected in 3 strings in parallel of 12 modules in series. The technical characteristics of the modules are shown in the Table II.

TABLE II
PV MODULES CHARACTERISTICS

Producer	Sharp Corporation
Model	NE-Q5E3H
Peak power	165 W
Dimension	1.575 m x 0.826 m
Efficiency	12.7%

The system includes an inverter of 4.8 kW suitable for the Italian electric grid (Table III).

TABLE III
INVERTER'S CHARACTERISTICS

Producer	SMA
Model	Sunny Boy 5000TL Multi-String
Peak power	4.8 kW
Efficiency	94.5%

The annual energy production (AC) estimated on the basis of the local meteorological conditions is about 6504 kWh with consequent annual carbon dioxide (CO_2) savings of approximately 3447 Kg . It means that for the expected lifetime of the plant, about 30 years, it will permit a reduction of about 103.41 tons in CO_2 emissions (Table IV).

TABLE IV
TECHNICAL CHARACTERISTICS OF THE PV SYSTEM

Nominal Power	5.94 kWp
Modules Number	36
Orientation	South-East
Tilt Angle	17 °
Irradiation on the PV System	69469 kWh
Annual Energy Production (AC)	6504 kWh

Annual Specific Productivity	1093 kWh/ kWp
Annual saving in CO_2 emissions	3447 kg

The total cost of the system is about 41580 € , equal to 7000 € for kWp.

The annual costs of the ordinary maintenance are hypothesized in the measure of 1% of the cost of the initial investment.

The cost of the extraordinary maintenance (the inverter substitution) in the tenth year of the PV system's life is hypothesized in measure of 10% of the cost of the initial investment.

Several indexes of financial feasibility were analyzed such as the annual energy inflation rate (4.5%), the annual inflation rate (2.5%), the "attualizzazione" rate (5%), the return of investment and the payback time (Table V). In the Fig.1 the cash flow is shown.

TABLE V
PV SYSTEM ECONOMICAL DATA

System Total Cost	41580 €
Payback Time	10 years

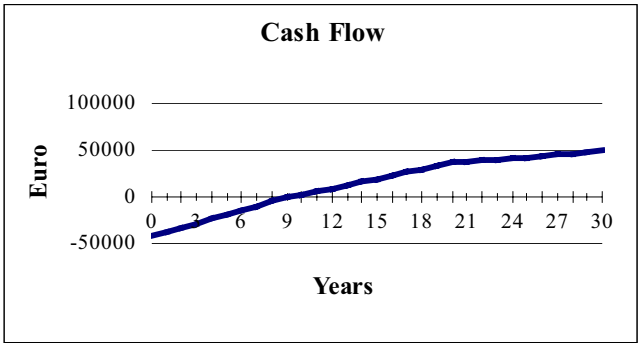

Fig. 1 Cash Flow of the project: the operative seat of the Park

B. The ticket office

The system planned for the ticket office of the Park is a partially integrated system and it was planned on the annual electric energy consumptions.

It is a 3.96 kWp grid-connected PV array located on the roof of the building and it occupies a shadows-free area of about 31 m^2.

The grid-connected plant is realized with 24 polycrystalline PV modules of 165 Wp in standard conditions.

The modules are south facing on a roof that has 18° of inclination. The modules are connected in 2 strings in parallel of 12 modules in series. The technical characteristics of the modules are shown in the Table II.

The system includes an inverter of 2.8 kW suitable for the Italian electric grid (Table VI).

TABLE VI
INVERTER'S CHARACTERISTICS

Producer	SMA
Model	Sunny Boy 3000
Peak power	4.8 kW
Efficiency	93.6%

The annual energy production (AC) estimated on the basis of the local meteorological conditions is about 4551 kWh with consequent annual carbon dioxide (CO_2) savings of approximately 2412 Kg . It means that for the expected lifetime of the plant, about 30 years, it will permit a reduction of about 72.36 tons in CO_2 emissions (Table VII).

TABLE VII
TECHNICAL CHARACTERISTICS OF THE PV SYSTEM

Nominal Power	3.96 kWp
Modules Number	24
Orientation	South
Tilt Angle	18 °
Irradiation on the PV System	48932 kWh
Annual Energy Production (AC)	4551 kWh
Annual Specific Productivity	1147 kWh/ kWp
Annual saving in CO_2 emissions	2412 kg

The total cost of the system is about 27720 € , equal to 7000 € for kWp.

The annual costs of the ordinary maintenance are hypothesized in measure of 1% of the cost of the initial investment.

The cost of the extraordinary maintenance (the inverter substitution) in the tenth year of the PV system's life is hypothesized in measure of 10% of the cost of the initial investment.

Several indexes of financial feasibility were analyzed such as the annual energy inflation rate (4.5%), the annual inflation rate (2.5%), the "attualizzazione" rate (5%), the return of investment and the payback time (Table VIII). In the Fig.2 the cash flow is shown.

TABLE VIII
PV SYSTEM ECONOMICAL DATA

System Total Cost	27720 €
Payback Time	9 years

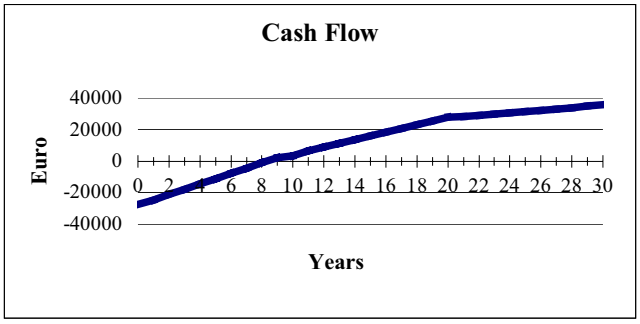

Fig. 2 Cash Flow of the project: the ticket office

C. The tourist camping

In the tourist camping there are eight bungalows: only five of them have a south-facing roof orientation. The system planned for these five bungalows of the tourist camping is a partially integrated system and was planned on the annual electric energy consumptions.

Each PV system is a 1.98 kWp grid-connected located on the roof of the bungalow and it occupies a shadows-free area of about 15 m^2 .

The grid-connected plant is realized with 12 polycrystalline PV modules of 165 Wp in standard condition.

The modules are south facing on a roof that has 20° of inclination. The technical characteristics of the modules are shown in the Table II.

The system includes an inverter of 1.8 kW suitable for the Italian electric grid (Table X).

TABLE X
INVERTER'S CHARACTERISTICS

Producer	Fronius
Model	Sunrise Midi Plus
Peak power	1.8 kW
Efficiency	93 %

The annual energy production (AC) estimated on the basis of the local meteorological conditions is about 2199 kWh with consequent annual carbon dioxide (CO_2) savings of approximately 1165 Kg. It means that for the expected lifetime of the plant, about 30 years it will mean a reduction of about 34.95 tons in CO_2 emissions (Table XI).

TABLE XI
TECHNICAL CHARACTERISTICS OF THE PV SYSTEM

Nominal Power	1.98 kWp
Modules Number	12
Orientation	South
Tilt Angle	20°
Irradiation on the PV System	24306 kWh
Annual Energy Production (AC)	2199 kWh
Annual Specific Productivity	1107 kWh/ kWp
Annual saving in CO_2 emissions	1165 kg

The total cost of the system is about 13860 € , equal to 7000 € for kWp.

The annual costs of the ordinary maintenance are hypothesized in measure of 1% of the cost of the initial investment.

The cost of the extraordinary maintenance (the substitution of the inverter) in the tenth year of the PV system's life is hypothesized in measure of 10% of the cost of the initial investment.

Several indexes of financial feasibility were analyzed such as the annual energy inflation rate (4.5%), the annual inflation rate (2.5%), the "attualizzazione" rate (5%), the return of investment and the payback time (Table X). In the Fig.3 the cash flow is shown.

TABLE X
PV SYSTEM ECONOMICAL DATA

System Total Cost	13860 €
Payback Time	9 years

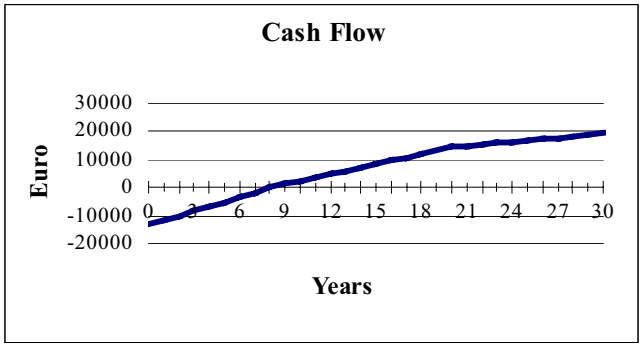

Fig. 3 Cash Flow of the project: the tourist camping

According to this study, the introduction of photovoltaic systems can convert Italian Natural Parks into electricity generators and also it will add new architectural structures in places without any particular land use.

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His research activity mainly deals with some studies on lighting engineering (light-pipes and atrium buildings). He also studies the renewable sources with particular attention to the photovoltaic system and to its applications. Finally he carries out the experimental and numerical analysis on natural convection in enclosures heated from below. The experimental setup is made up of two different equipments: the holographic interferometry to evaluate the heat transfer inside a cavity and the PIV (particle Image Velocimetry) to evaluate the dynamic behaviour connected with the heat transfer. He has the chair of Applied Physics at the "Università Politecnica delle Marche" (Ancona, Italy)
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